Wavelength Assignment for Wavelength-Reusable Multi-Carrier-Distributed Mesh Networks

Praphan Pavarangkoon, Nattapong Kitsuwan, and Eiji Oki
Department of Information and Communication Engineering,
The University of Electro-Communications, Tokyo, Japan

***Abstract*—This paper proposes a wavelength assignment scheme for wavelength-reusable multi-carrier-distributed (WRMD) mesh networks to minimize the number of required wavelengths. The results show that the proposed scheme with regenerating carriers more than two times per wavelength achieves at most 60% reduction of the number of required wavelengths, compared to wavelength division multiplexing (WDM) network without carrier regeneration.**

I. Introduction

In conventional wavelength division multiplexing (WDM) networks, there is no wavelength reusable capability, more laser diodes (LDs) are needed to provide sufficient wavelengths to meet the explosive demand for network bandwidth. This, unfortunately, will raise energy consumption and development cost. Moreover, the complexity of wavelength management increases with increasing of the number of wavelengths.

A multi-carrier-distributed optical network with wavelength reuse capability [1], [2] is an alternative solution. This network is called the wavelength-reusable multi-carrier-distributed (WRMD) network. The WRMD network places a multi-carrier light source (MCLS) at an MCLS node, as a light source. The MCLS emits several optical line spectra with uniform frequency intervals. The individual wavelengths are used as optical carriers. MCLS generates the optical carriers and passes them to all requesting source nodes for lightpath establishment. Furthermore, each node in the WRMD network is equipped with an optical carrier regenerator (OCR) [1]. The OCR allows the nodes to reuse a wavelength to satisfy multiple disjoint requested lightpaths. Wavelength assignment for the WRMD network was proposed in [2]. None of the source nodes includes an LD. Each requested lightpath directly receives a generated optical carrier from the MCLS node or a reused optical carrier from destination node of other requested lightpath. Therefore, the source node has several light sources from which it can receive an optical carrier. Carrier distribution was managed to minimize the number of wavelengths. However, only a ring topology was considered. In the ring topology, an optical carrier connection, which connects the MCLS node and a lightpath or two lightpaths, is uniquely determined because the connecting direction is limited. On the other hand, in the mesh topology, several of optical carrier connection candidates must be considered. Therefore, the mesh topology makes distributing carrier wavelengths and assigning wavelengths much more complex than is true with the ring topology.

This paper proposes a wavelength assignment scheme for WRMD mesh networks to minimize the number of required wavelengths. The scheme has two steps. First, chains of lightpaths are created. Each chain of lightpaths consists of carrier lightpaths and requested lightpaths; herein, we introduce three requested lightpath selection policies to select requested lightpaths for creating a chain of lightpaths. Second, after all carrier lightpaths and requested lightpaths are included in the chains of lightpaths, wavelengths are assigned for the chains of lightpaths, one for each chain of lightpaths. Moreover, we investigate the number of required wavelengths in three requested lightpath selection policies.

II. Node Architecture for WRMD Network

A WRMD network was introduced to greatly simplify the need for complicated wavelength management. An example of the WRMD network with mesh topology, as shown in Fig. 1, consists of three nodes and an MCLS node, whereas the MCLS node also works as a node. Each node consists of modulators (MODs), receivers (RXs), OCR, and reconfigurable optical drop-add-drop multiplexer (RODADM). The MCLS node consists of a wavelength selective switch (WSS) and an MCLS device. The MCLS node is used to generate and provide optical carrier to all requested lightpaths.

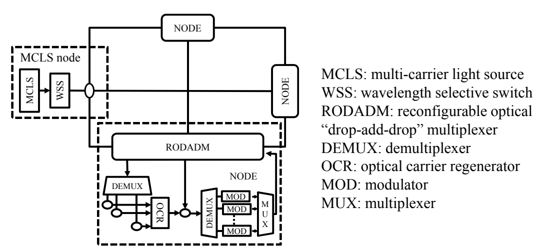


Fig. 1. WRMD network architecture

At each node in the WRMD network, specific optical carriers are dropped by the RODADM of the source nodes and used for uplink transmission. A data stream is added to the network, and is modulated with the optical carrier, while the data is dropped at the destination nodes. Thus, the RODADM for multi-carrier distribution is not only responsible for adding and dropping data, but also is used to drop optical carriers. The dropped data stream and optical carrier are separated and regenerated by an OCR. The regenerated optical carrier is re-injected into the network, and is used to establish other requested lightpath.

III. Wavelength Assignment for WRMD Network

We provide a wavelength assignment scheme to reduce number of required wavelengths for WRMD mesh networks.

There are two steps in the scheme. In the first step, chains of lightpaths are created. In this step, a requested lightpath is selected to establish connection, based on a requested lightpath selection policy. An optical carrier is generated from the MCLS node, and travels along a carrier lightpath to the selected requested lightpath. The optical carrier is regenerated at the ending node of the selected requested lightpath. Other requested lightpath is selected. The requested optical carrier travels along other carrier lightpath to the requested lightpath. A path from the MCLS node to the ending node of the last requested lightpath, including carrier lightpaths and requested lightpaths, is called a chain of lightpaths. The second step, each chain of lightpaths is assigned by a wavelength. The wavelength assignment is then solved as a graph coloring problem. Moreover, policies for creating the chain of lightpath, namely random, near ending node (NE), and near MCLS node (NM), are introduced to create the chains of lightpaths.

A. Random Policy

A non-selected requested lightpath is a requested lightpath that is not included in any chain of lightpaths. Each non-selected requested lightpath is randomly selected. This policy is simple since need to calculate only the shortest distance either between the MCLS node and the selected requested lightpath, or between the destination of requested lightpath and the selected requested lightpath.

B. Near Ending Node (NE) Policy

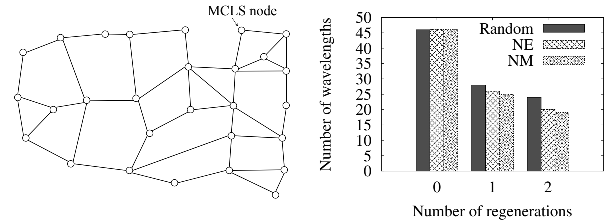
The NE policy takes into account a requested lightpath with the shortest distance from a starting pointer (SP) to the source node of requested lightpath. The SP is moved to the destination node of requested lightpath every time when the requested lightpath is selected. This policy easily manages the requested lightpaths since it uses only one pattern to select each requested lightpath. However, there are some disadvantages of this policy since it has to calculate the shortest distance between the destination of requested lightpath and the non-selected requested lightpath every time.

C. Near MCLS Node (NM) Policy

This policy considers a requested lightpath with the shortest distance from SP to the source node of requested lightpath and after that SP is set to the destination node of requested lightpath. In addition, after a chain of lightpaths is created, SP is set at the MCLS node. The NM policy decreases the calculation time of NE policy. Moreover, it has more chance to complete the chain of lightpaths successfully since the average of carrier lightpaths is low.

IV. Performance Evaluation

The performance of the proposed scheme is evaluated by computer simulation in terms of the number of required wavelengths. We consider a network topology, namely U.S long distance network as shown in Fig. 2(a). The number of requested lightpaths is 50. Furthermore, we compare the conventional WDM network, in which the allowable number of carrier regenerations is zero, with the WRMD mesh network with various allowable number of carrier regenerations.



(a) Network topology

(b) Number of required wavelengths in different requested lightpath selection policies

Fig. 2. U.S. long distance network

Moreover, we investigate the number of required wavelengths in three requested lightpath selection policies.

Figure 2(b) shows the number of required wavelengths in the different three policies for U.S. long distance network. It notes that the conventional WDM network have a large number of required wavelengths, whereas the proposed scheme decreases the number of required wavelengths with increasing of the allowable number of carrier regeneration. Furthermore, a single regeneration reduces the number of required wavelengths by more than 40%. However, a double regeneration of the NM policy reduces the number of required wavelengths 60% from the conventional scheme. This is due to the fact that the NM policy takes into account a requested lightpath with the shortest distance from the MCLS node to the source of a requested lightpath, which has a chance to complete the chain of lightpaths successfully more than other policies. On the other hand, the random policy is proceeded in a distributed manner. In the NE policy, the scheme considers a requested lightpath with the shortest distance from SP to the source of a requested lightpath and after that SP is set to the destination of the requested lightpath. As a result, both random and NE policies have a chance to complete the creation of chains of lightpaths less than the NM policy.

V. Conclusion

This paper proposed a wavelength assignment scheme for WRMD mesh networks to minimize the number of required wavelengths for lightpath establishment. The scheme has two steps. The first step is to create chains of lightpaths and the second step is to assign a wavelength for each chain of lightpaths. In addition, three requested lightpath selection policies, which include the random, NE, and NM policies, are introduced in this paper to create the chains of lightpaths. The results showed that a single regeneration of three requested lightpath selection policies reduces the number of required wavelengths by more than 40%. Moreover, a double regeneration of NM policy reduces the number of required wavelengths by at most 60%, compared to the conventional scheme.

References

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